CRYSTAL-FACE Mesoscale Model Forecast Intercomparison

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ARPS – Advanced Regional Prediction System, NASA LaRC

Donghai Wang, Patrick Minnis

RAMS – Regional Atmospheric Modeling System, CSU

Sue van den Heever, William Cotton

MM5 – Mesoscale Model, GSFC, UMD, and RU

Yansen Wang, David Starr

The Key West forecast team was:

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Ken Pickering, University of Maryland
Rennie Selkirk, NASA-Ames/Bay Area Environmental Research Institute
Gera Stenchikov, Rutgers
Adrian Tuck, NOAA-Aeronomy Lab

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plus the NWS forecasters

Key West Weather Detachment, USN:

LCPO Dean Kontinos and his active duty forecasting staff
Mr. Al Ceier

Objectives of Forecast:

Provide major characteristics of convective activity: timing, location, intensity, anvil evolution to support aircraft observations

Objectives of Forecast Intercomparison:

- As a part of a post-mission analysis provide characterization of convective activity during the entire period of campaign
- Analyze major driving mechanism of observed storms
- Define major factors which affected convection forecasts
- Provide recommendations for future improvements of convection forecasts

ARPS
- ETA fields for initial and boundary conditions (40-km resolution)
- L50, top at 25 km
- Ice microphysics by Lin and Tao; Radiation by Chou&Suarez
- Kain-Fritsch convective parameterization; Soil moisture from Eta-model analysis
- 15 km, 5 km, and 3 km resolution nested grids, External domain ~2000x2000 km

RAMS
- ETA fields for initial and boundary conditions (80-km resolution)
- L36 top at 20 km
- Ice microphysics by Cotton; Radiation by Harrington
- Mellor and Yamada boundary layer turbulence
- Kuo convective parameterization, Climatological soil moisture
- 48, 12, 3-km resolution nested grids, External domain ~2500x4000 km

MM5
- Eta fields for initial and boundary conditions (40-km resolution)
- L23, top at 50 hPa
- Ice microphysics by Lin/Rutledge/Hobbs; Radiation by Dudhia
- Blackadar boundary layer turbulence, Climatological soil moisture
- Kain-Fritsch convective parameterization in 15-km res. domain
- 15 and 5-km resolution nested grids, External domain ~1000x1000 km

Forecasts of Convective Activity for Field Projects

2-D cloud-model forecast:

North Dakota Thunderstorm Project

(*Boe et al*. 1992; *Kopp and Orville*, 1994; *Stenchikov et al*., 1996)

STERAO-A project in Colorado

(*Dye et al*., 2001; *DeCaria et al.*, 2000)

3-D cloud-model forecast

STORMTIPE-91, STORMTIPE-95

(*Wicker et al.*, 1997; *Elmore et al*., 2002)

3-D mesoscale models with nonhydrostatic nested region

CRYSTAL-FACE: 3-D Nonhydrostatic Downscaling of ETA-model forecast

Forecast Evaluation:

Statistical analysis for all cases:

Timing of convection

Location

Forcing

Detailed Analysis of Forecasts for 7/16, 7/21, 7/23 Cases:

Timing of convection

Location

Forcing

Strength and Duration

Altitude, Stratospheric Penetration

Inflow and Detrainment

Size of Anvil

Transport in the Upper Troposphere

Forcings of Convective Instability

Local Forcings:

CAPE- Convective Available Potential Energy

SREH – Storm Relative Helicity

BRN – Bulk Richardson Number

Surface heating, Evaporation, See breezes

Mesoscale Forcings:

Vertical velocity

Mesoscale circulation features

Distribution of regions with high convective instability

Position of subtropical jet

Meso- and global- scale circulation

Preliminary Analysis of Forecast Skill

15 days (from 7/5 to 7/29) with model evaluation were considered

Standard 2x2 Contingency Statistics:

		OBSERVED	
		Yes	**No**
FORECAST	**Yes**	a	b
	No	c	d

Probability of Detection (POD) = a/(a+c)

M-convection – Caused by a mesoscale forcing

L-convection – Caused by local forcing, e.g., land heating, breeze convergence

T-convection - M-convection + L-convection

Probability of detection

	L-convection	M-convection	T-convection
ARPS	0.556	0.769	0.682
RAMS	0.778	0.231	0.455
MM5	0.889	0.385	0.591

Analysis of Model performance for specific case-studies

7/16 - M-convection in the morning and L-convection in the afternoon

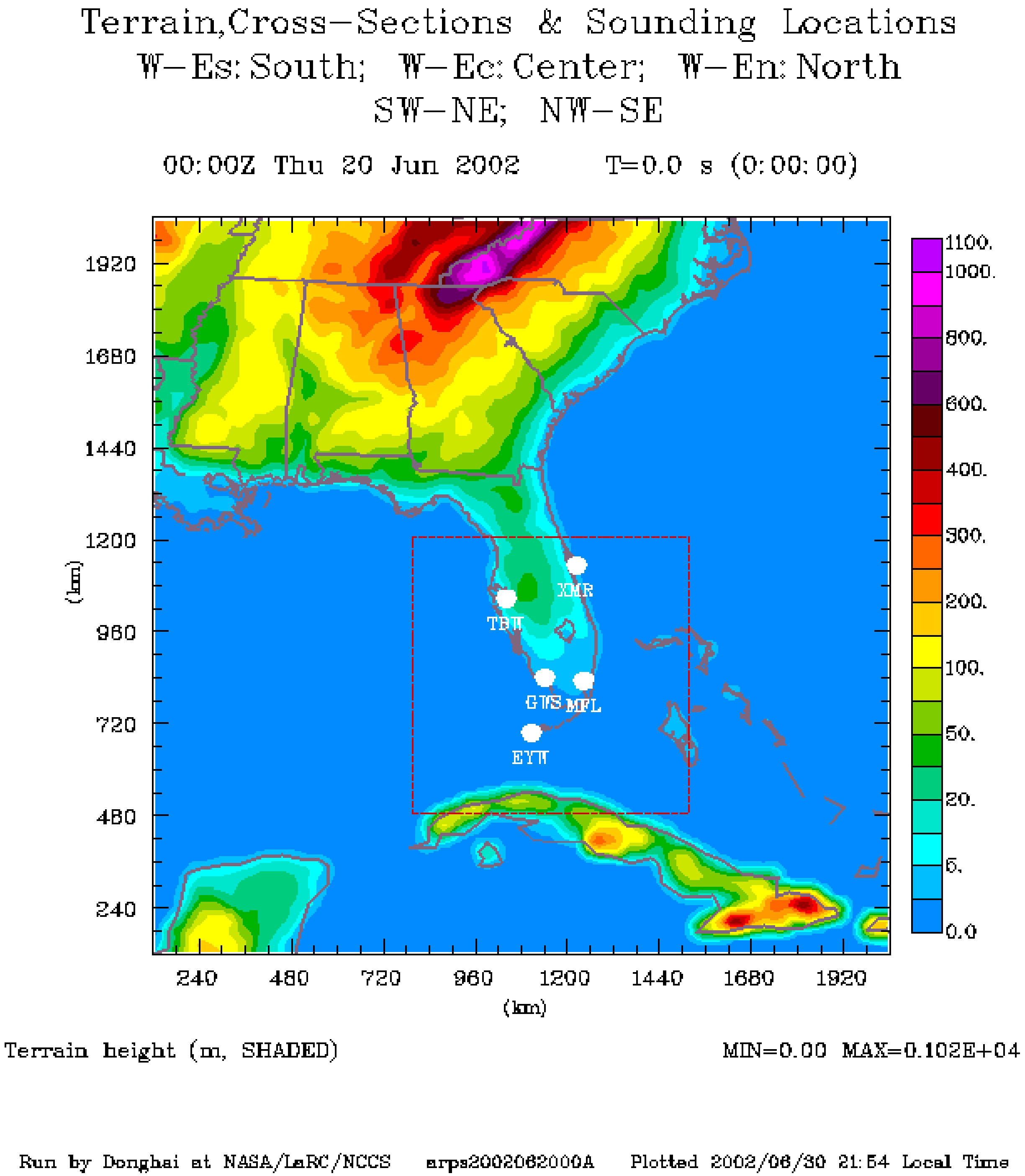
All models captured convection

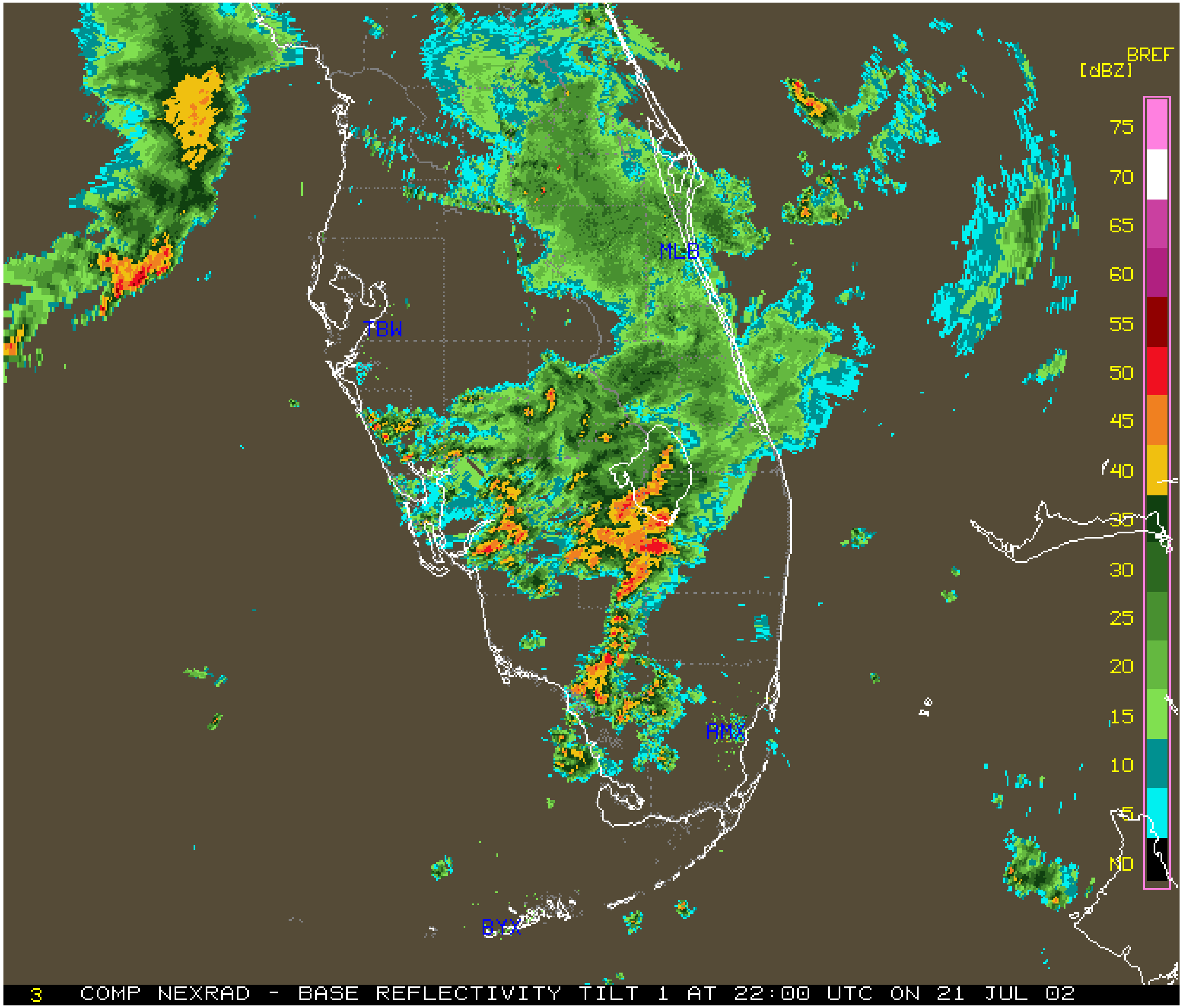
7/21 – M-convection

RAMS and MM5 produced reasonable forecast

7/23 – M-convection

All models failed


Terrain,Cross-Sections & Sounding Locations
W-Es: South; W-Ec: Center; W-En: North
SW-NE; NW-SE
00:00Z Thu 20 Jun 2002 T=0.0 s (0:00:00)
1920
1680
1440
1200
960
720
480
240
(km)
240 480 720 960 1200 1440 1680 1920
(km)
XMR
TBW
GWS
MFL
EYW
1100.
1000.
800.
600.
400.
300.
200.
100.
50.
20.
5.
0.0
Terrain height (m, SHADED)
MIN=0.00 MAX=0.102E+04
Run by Donghai at NASA/LaRC/NCCS arps2002062000A Plotted 2002/06/30 21:54 Local Time


BREF
[dBZ]
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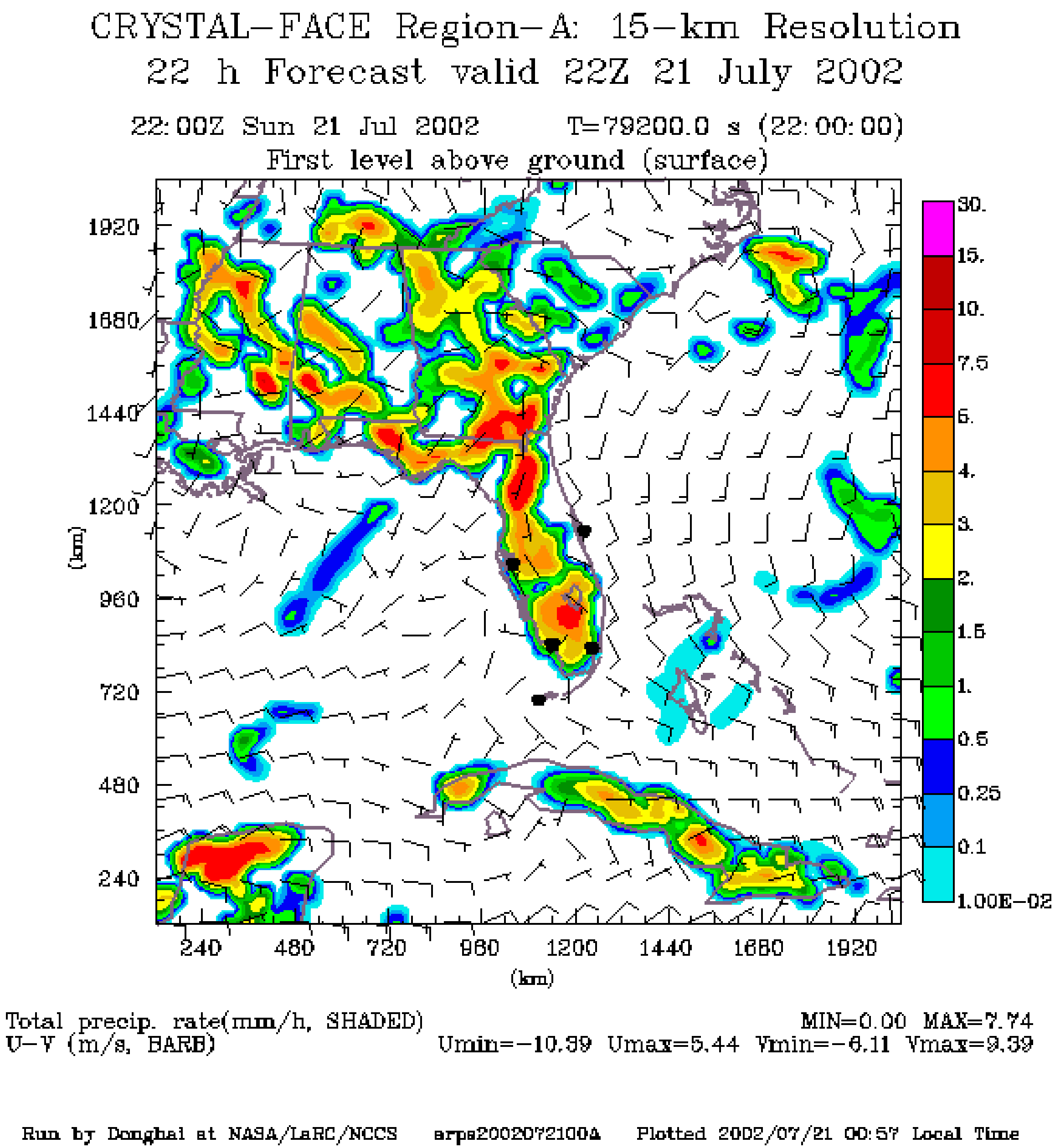
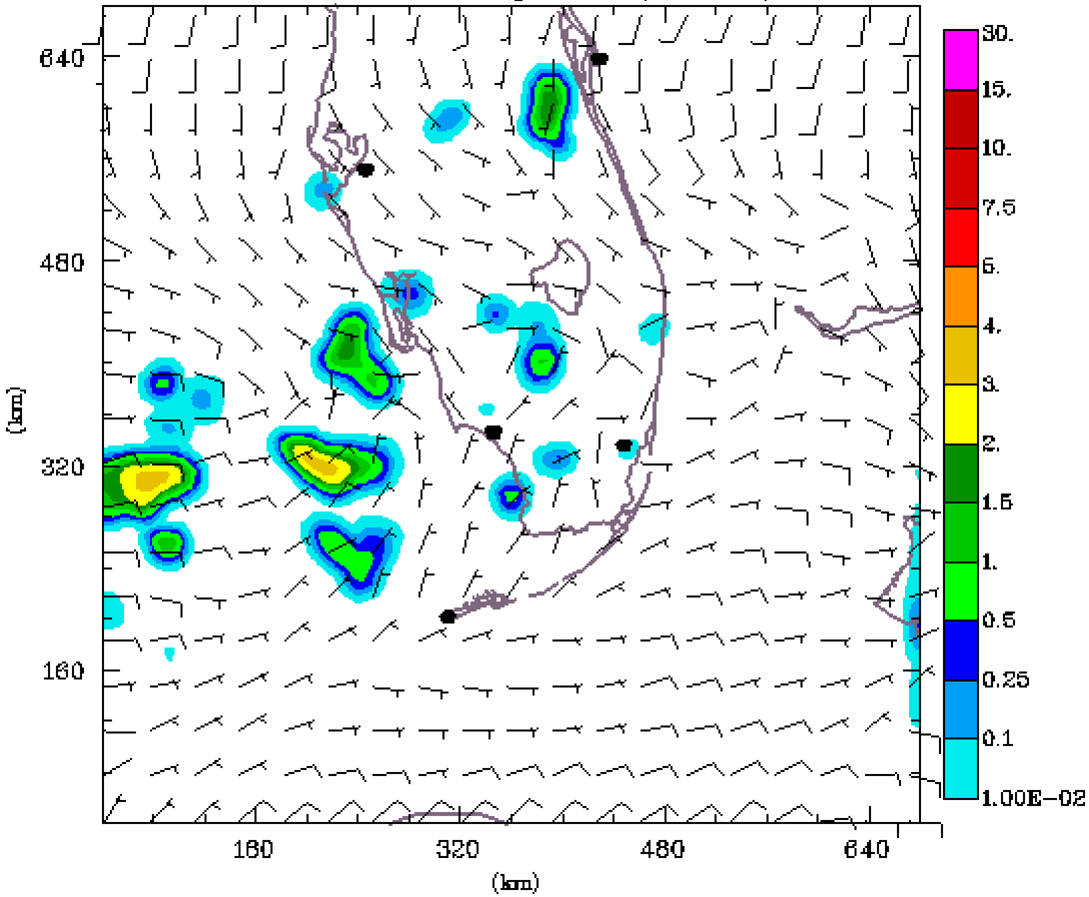
MLB
TBW
AMX
BYX
3 COMP NEXRAD - BASE REFLECTIVITY TILT 1 AT 22:00 UTC ON 21 JUL 02


CRYSTAL-FACE Region-A: 15-km Resolution
22 h Forecast valid 22Z 21 July 2002
22:00Z Sun 21 Jul 2002 T=79200.0 s (22:00:00)
First level above ground (surface)
(km)
Total precip. rate(mm/h, SHADED) MIN=0.00 MAX=7.74
U-V (m/s, BARB) Umin=-10.39 Umax=5.44 Vmin=-6.11 Vmax=9.39
Run by Donghai at NASA/LaRC/NCCS arps2002072100A Plotted 2002/07/21 00:57 Local Time

CRYSTAL-FACE Region-B: 5-km Resolution
16 h Forecast valid 22Z 21 July 2002

22:00Z Sun 21 Jul 2002 T=57600.0 s (16:00:00)
First level above ground (surface)



Total precip. rate(mm/h, SHADED) MIN=0.00 MAX=3.58
U-V (m/s, BARB) Umin=-6.26 Umax=2.88 Vmin=-4.23 Vmax=5.66

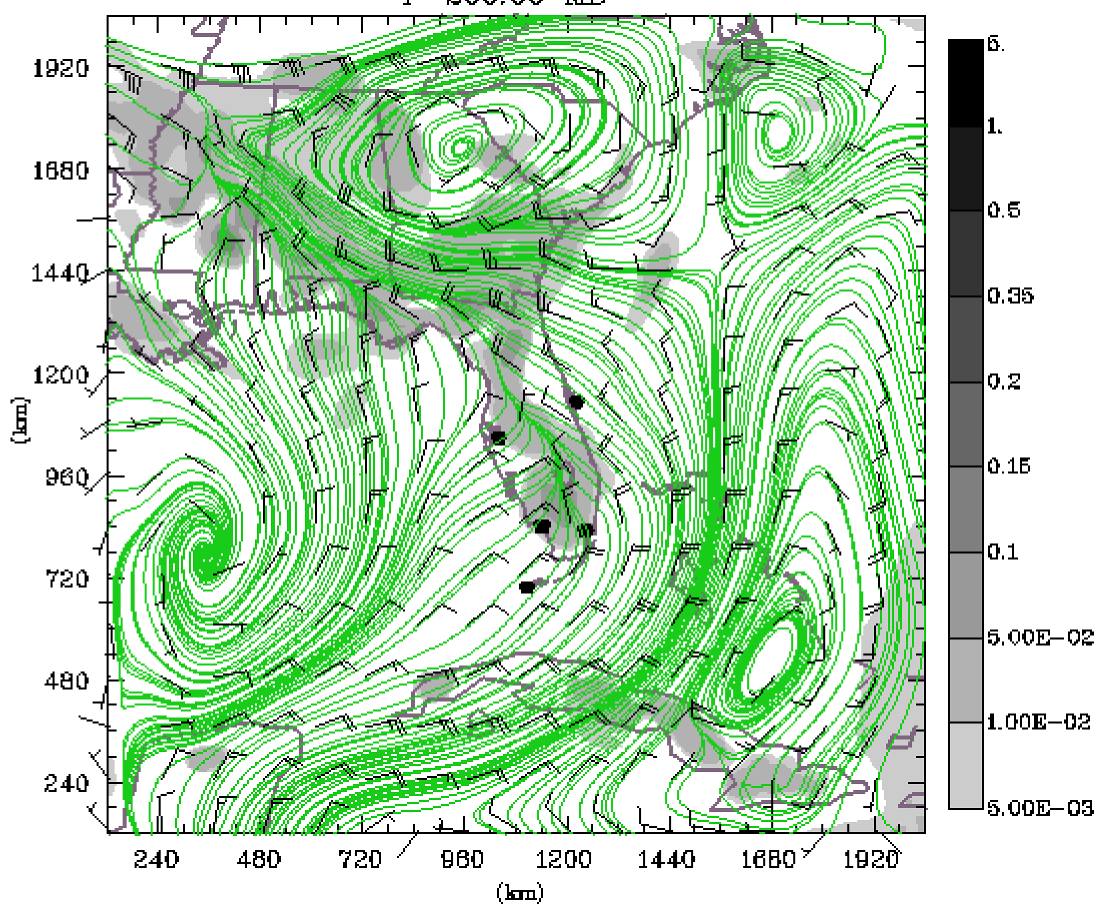
Run by Donghai at NASA/LaRC/NCCS arps2002072106B Plotted 2002/07/21 06:47 Local Time

CRYSTAL-FACE Region-A: 15-km Resolution

22 h Forecast valid 22Z 21 July 2002

22:00Z Sun 21 Jul 2002 T=79200.0 s (22:00:00)

P=200.00 MB

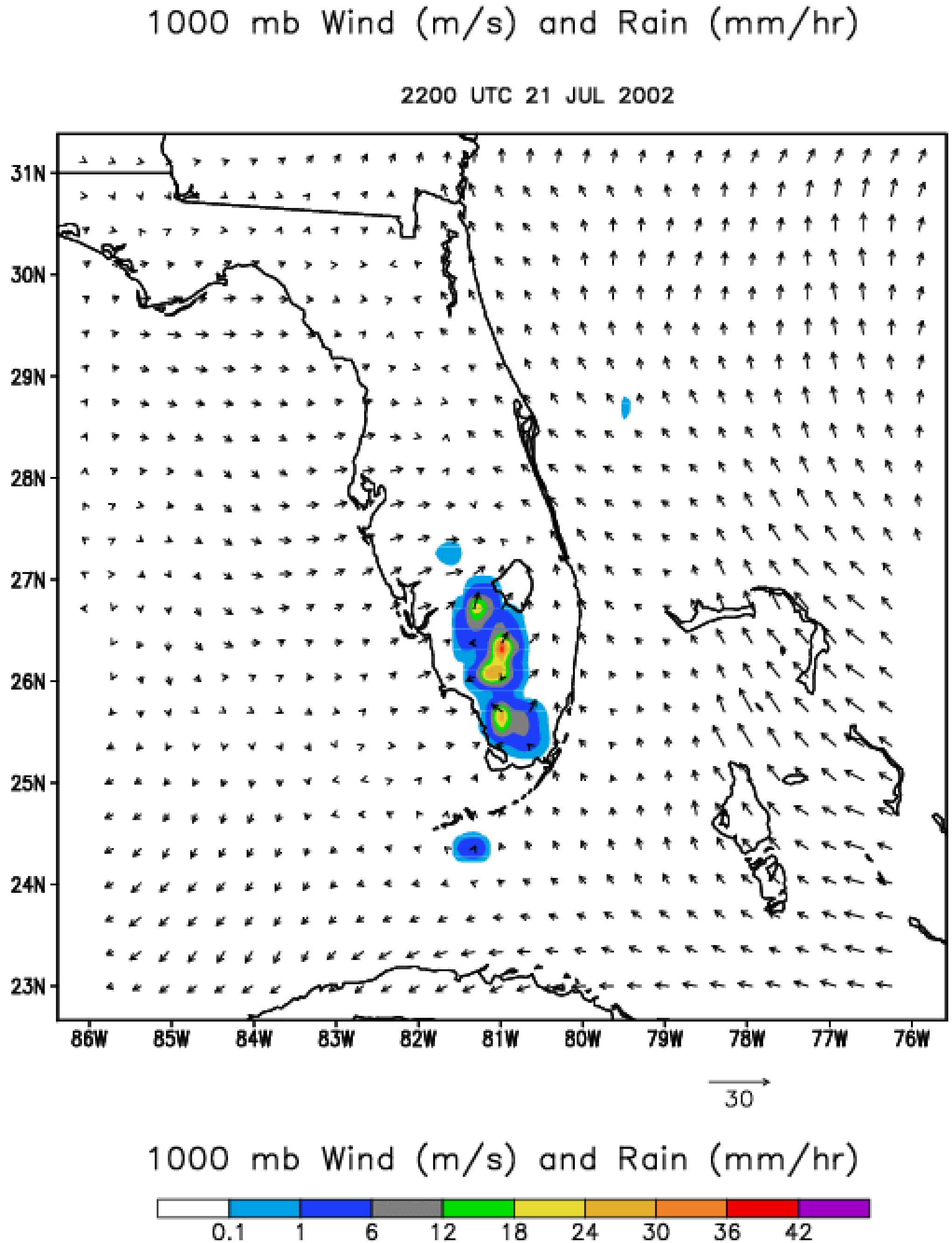


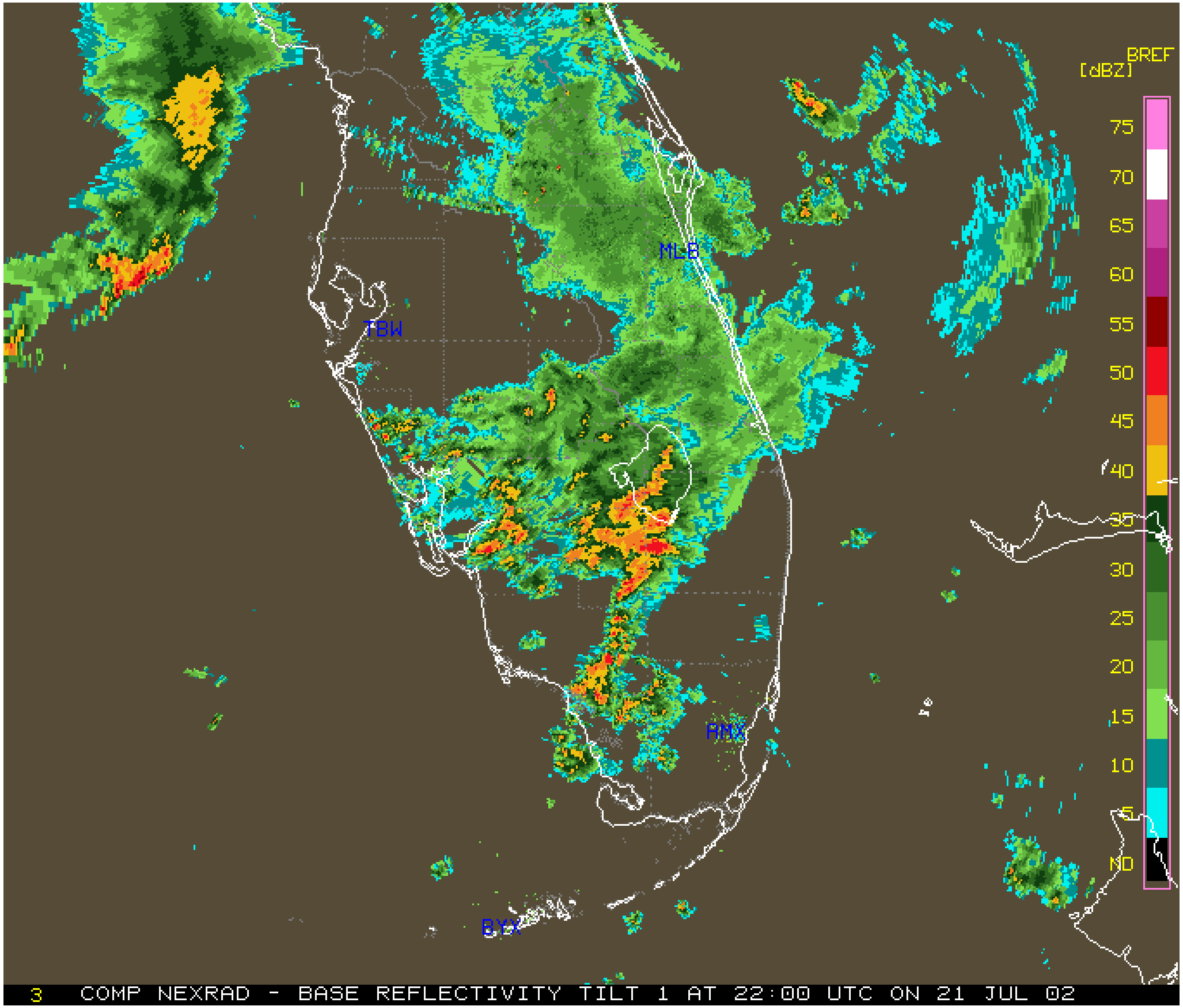
Total water (g/kg, SHADED) MIN=0.00 MAX=0.141

U-V STREAMLINE

U-V (m/s, BARB) Umin=-25.47 Umax=15.11 Vmin=-12.87 Vmax=13.71

Run by Donghai at NASA/LaRC/NCCS arps20020721004 Plotted 2002/07/21 00:57 Local Time


1000 mb Wind (m/s) and Rain (mm/hr)
2200 UTC 21 JUL 2002
31N
30N
29N
28N
27N
26N
25N
24N
23N
86W
85W
84W
83W
82W
81W
80W
79W
78W
77W
76W
30
1000 mb Wind (m/s) and Rain (mm/hr)
0.1
1
6
12
18
24
30
36
42


BREF
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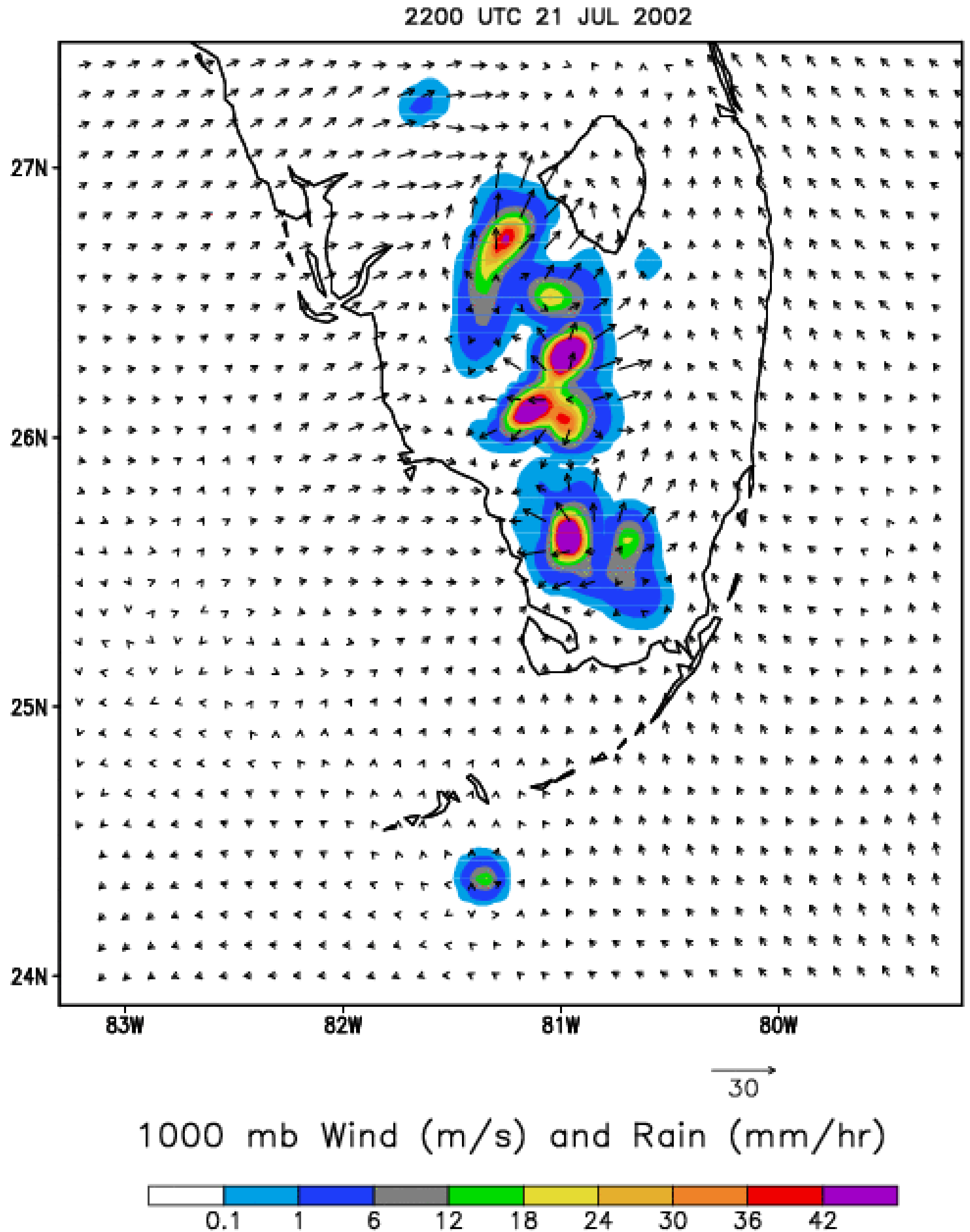
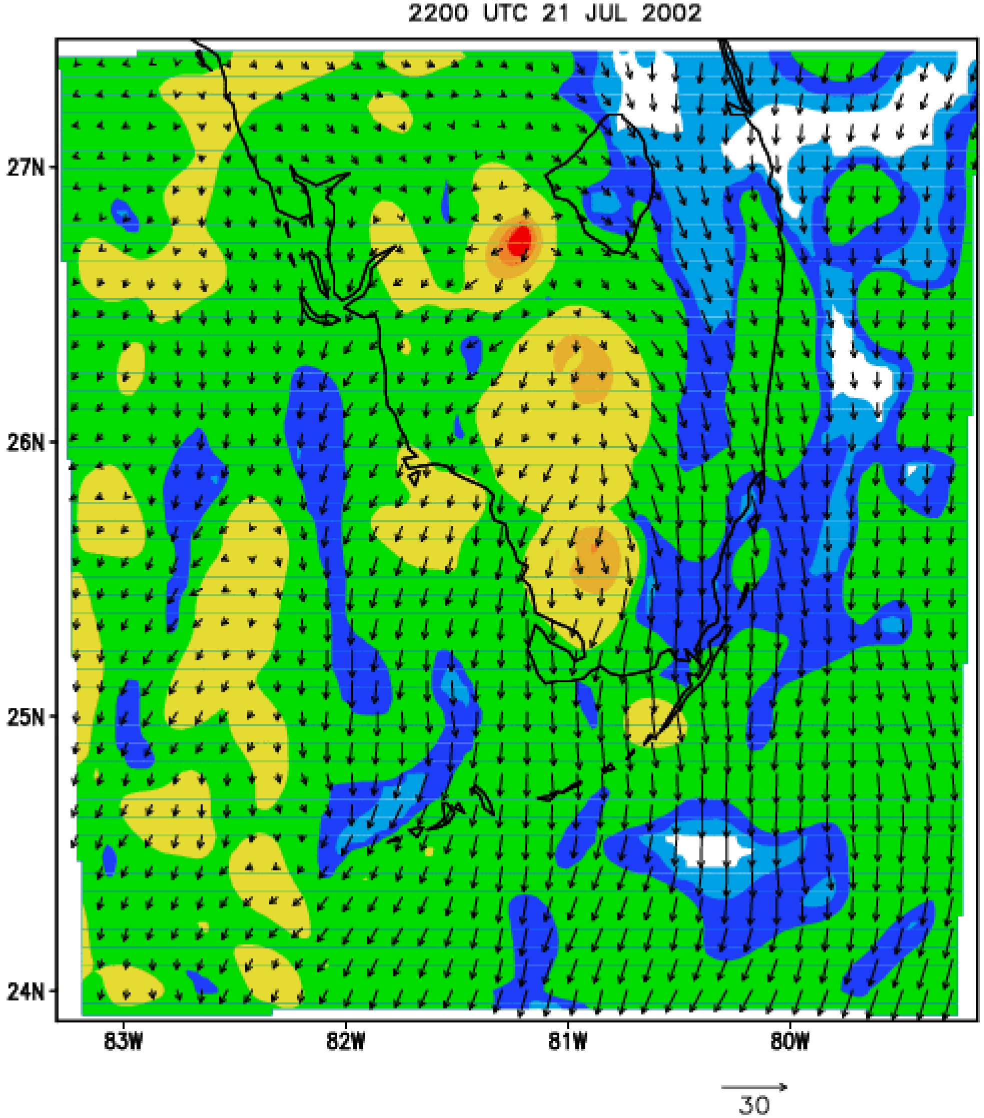
AMX
BYX
3 COMP NEXRAD - BASE REFLECTIVITY TILT 1 AT 22:00 UTC ON 21 JUL 02

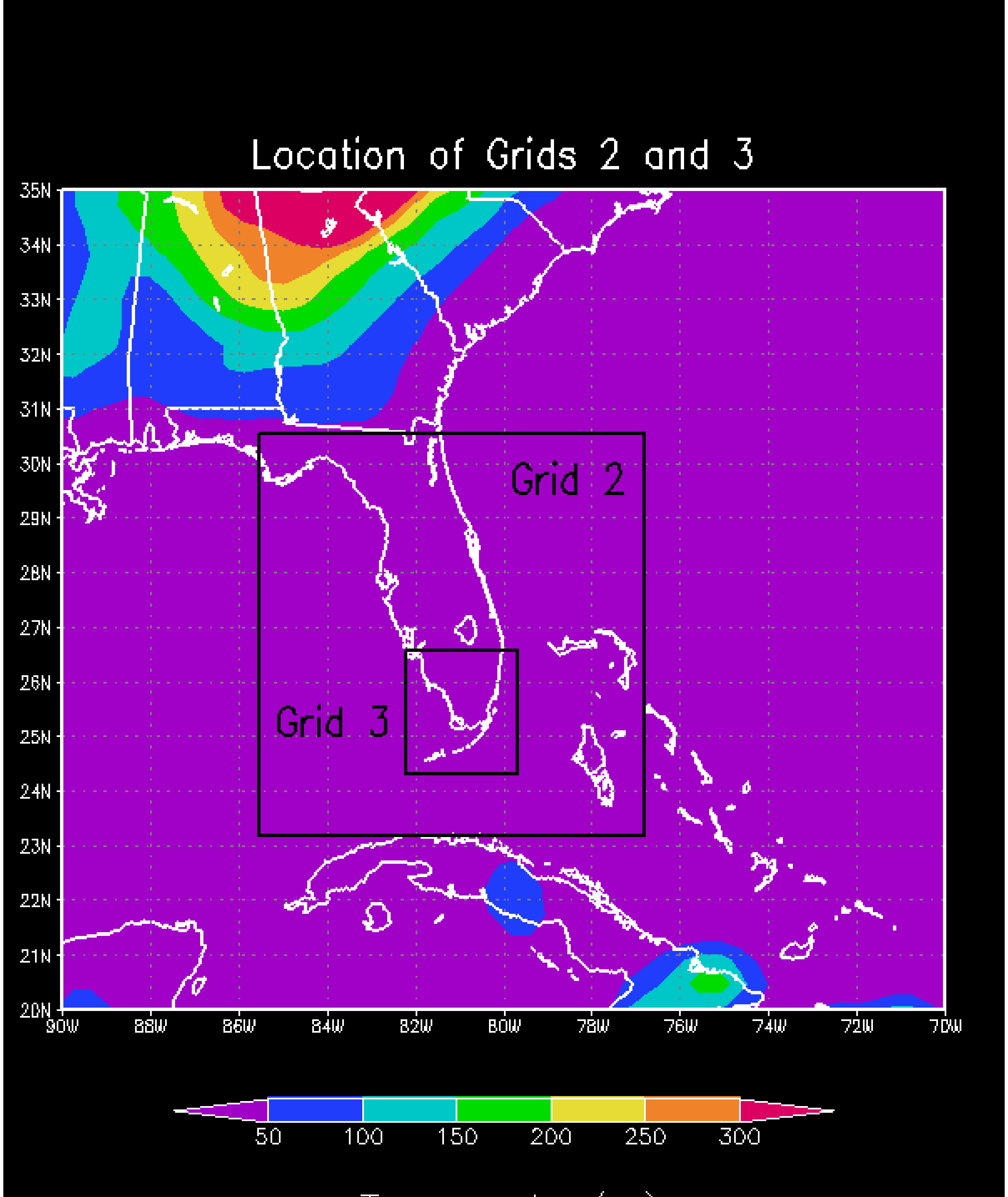
1000 mb Wind (m/s) and Rain (mm/hr)



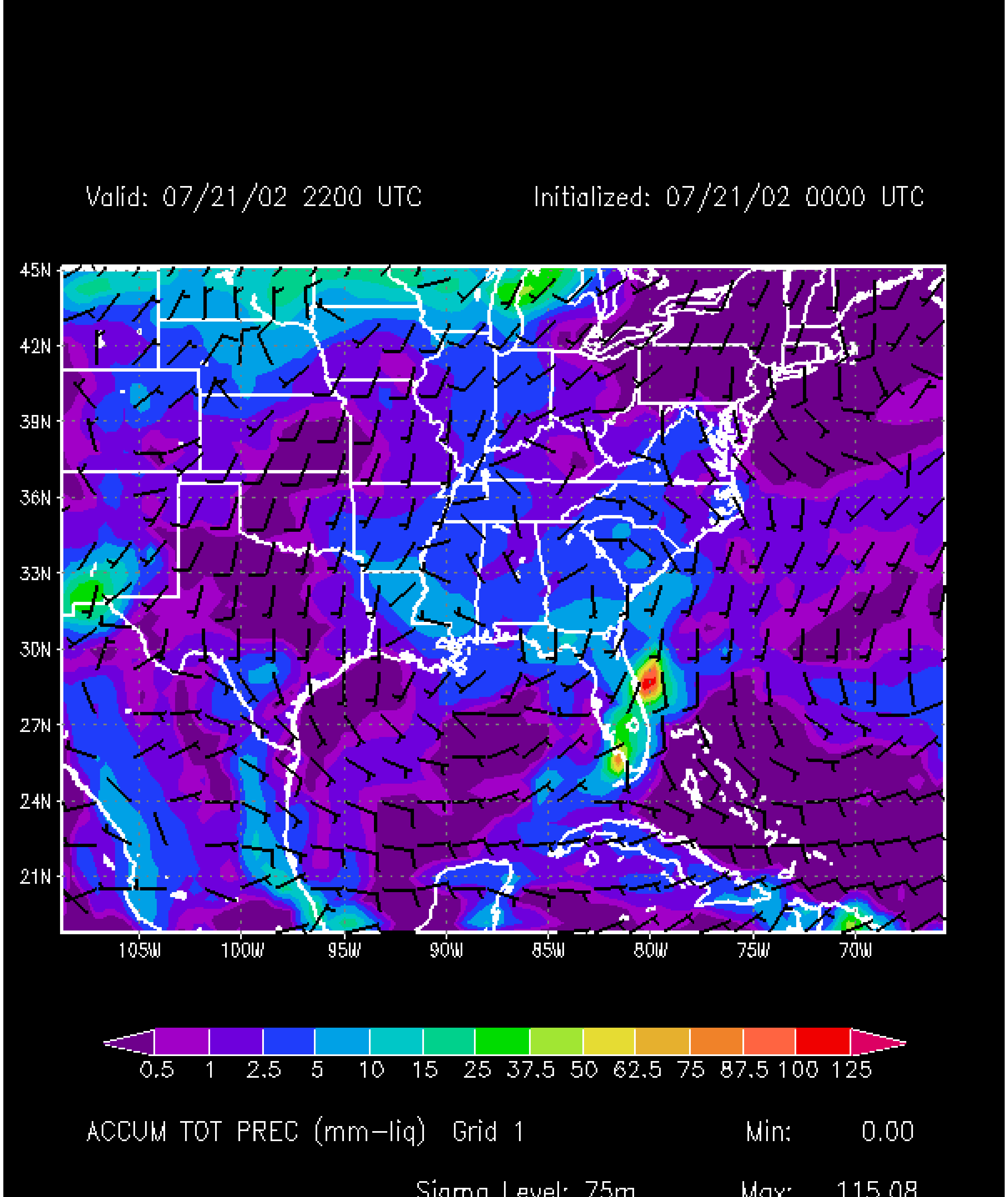
200 mb Hydrometeor (g/kg) and wind (m/s)



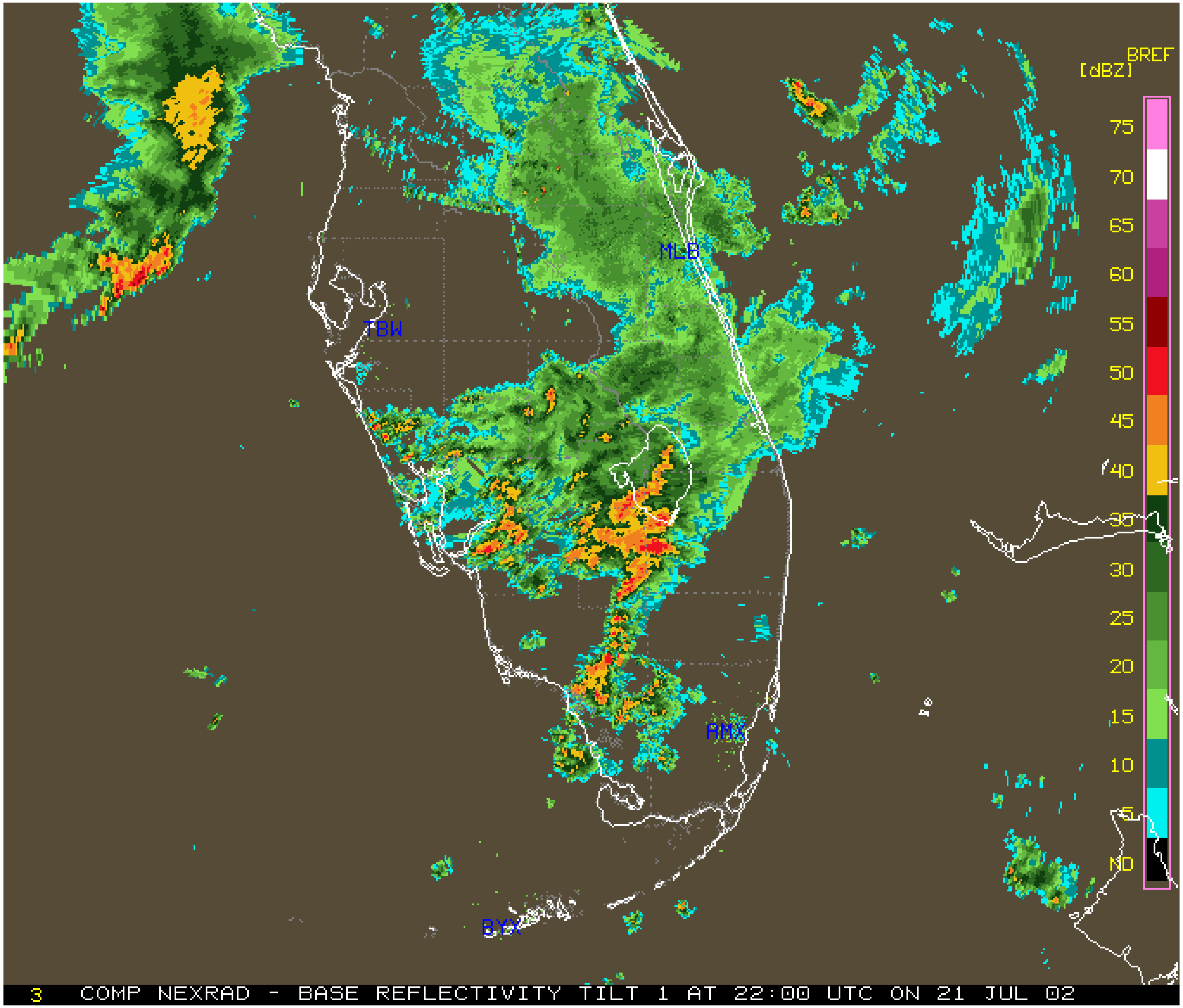
200 mb Hydrometeor (g/kg) and wind (m/s)



Location of Grids 2 and 3
Grid 2
Grid 3
35N
34N
33N
32N
31N
30N
29N
28N
27N
26N
25N
24N
23N
22N
21N
20N
90W
88W
86W
84W
82W
80W
78W
76W
74W
72W
70W
50
100
150
200
250
300



Valid: 07/21/02 2200 UTC
Initialized: 07/21/02 0000 UTC
45N
42N
39N
36N
33N
30N
27N
24N
21N
105W
100W
95W
90W
85W
80W
75W
70W
0.5 1 2.5 5 10 15 25 37.5 50 62.5 75 87.5 100 125
ACCUM TOT PREC (mm-liq) Grid 1
Min: 0.00
Sigma Level: 75m
Max: 115.08



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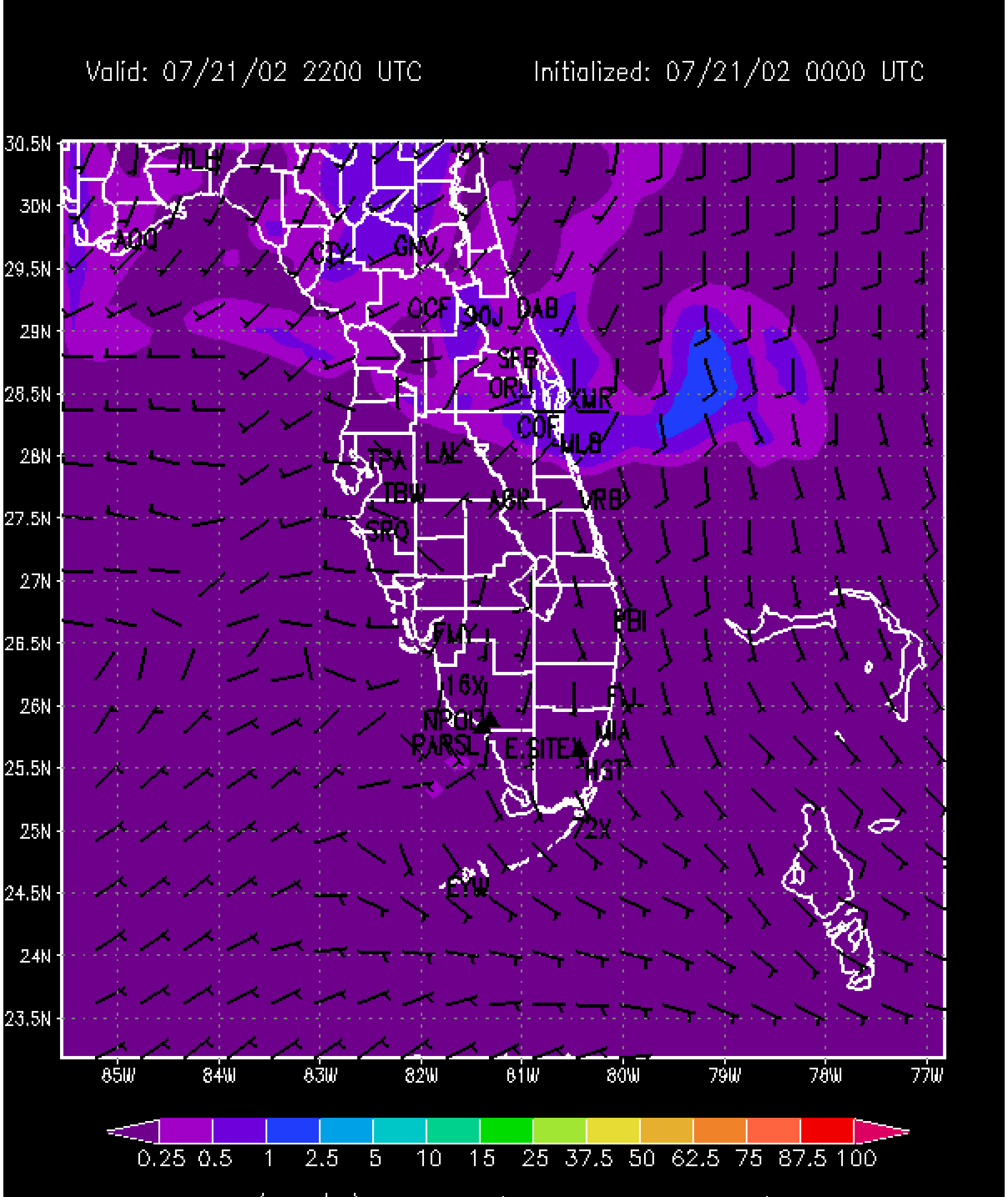
3 COMP NEXRAD - BASE REFLECTIVITY TILT 1 AT 22:00 UTC ON 21 JUL 02


Valid: 07/21/02 2200 UTC
Initialized: 07/21/02 0000 UTC
30.5N
30N
29.5N
29N
28.5N
28N
27.5N
27N
26.5N
26N
25.5N
25N
24.5N
24N
23.5N
85W
84W
83W
82W
81W
80W
79W
78W
77W
TLH
AQQ
CTY
GNV
OCF
X60J
DAB
SFB
ORL
XMR
COF
MLB
TPA
LAL
TBW
ABR
VRB
SRQ
PBI
FMY
16X
FLL
NPOC
MIA
PARSL
E.SITE
HST
72X
EYW
0.25
0.5
1
2.5
5
10
15
25
37.5
50
62.5
75
87.5
100

CONCLUSIONS

•The mesoscale models used for CF study are able to statistically reproduce timing and spatial distribution of convective activity but have problems forecasting individual convective storms

•Forecast skill is sensitive to the domain settings and resolution

•A coarse-resolution forecast is better than a fine-resolution one, when mesoscale forcing is dominant

•A fine resolution forecast is better when local forcing is dominant

•The ARPS 15-km forecast is often inconsistent with the 5 and 3-km forecast because of one-way boundary conditions for a nested grids; ARPS 15-km forecast was very useful when mesoscale forcing is important

•In MM5 15 and 5-km forecast are fairly consistent; MM5 5-km forecast tends to underestimate the size of the anvil because of relatively low spatial resolution

•RAMS tends to underestimate overall convective activity, but overestimates the strength of individual convective cells

Further Developments:

- Conduct more refined statistical analysis for the entire July using output from the models

- Conduct an extended analysis for the 3 specific selected cases

- Combine this material in a paper with contributions from all forecast teams